

# **TOWARDS AN INTERPLANETARY INTERNET: A PROPOSED STRATEGY FOR STANDARDIZATION**

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**SpaceOps 2002**

**Track 5: STANDARDIZATION and ENABLING TECHNOLOGIES**

**Houston, USA**

**October 2002**

# What is CFDP?

- ❖ The CCSDS File Delivery Protocol is an internationally standardized mechanism to deliver files of space mission data end-to-end through a space network via a series of store-and-forward hops, using custody transfer techniques
- ❖ The current CFDP ("Build 1") provides non-routed, non-custodial delivery through a single hop.

*It supports:*

- the user application

*And consists of:*

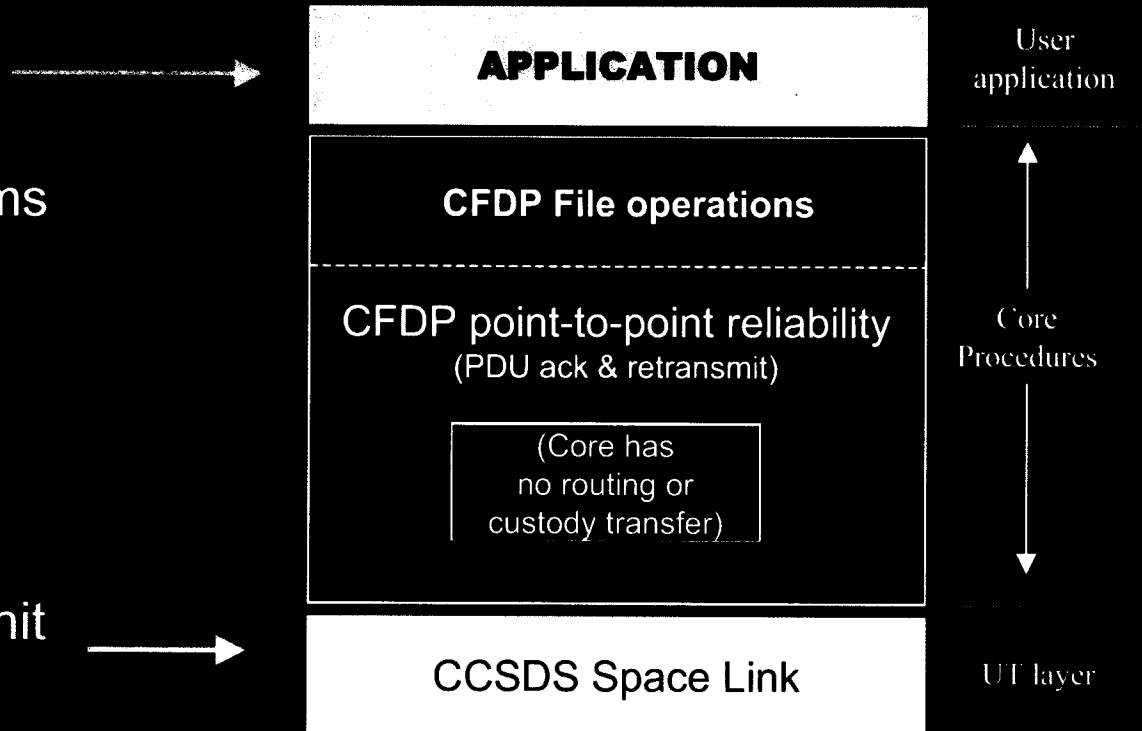
- file handling mechanisms

+

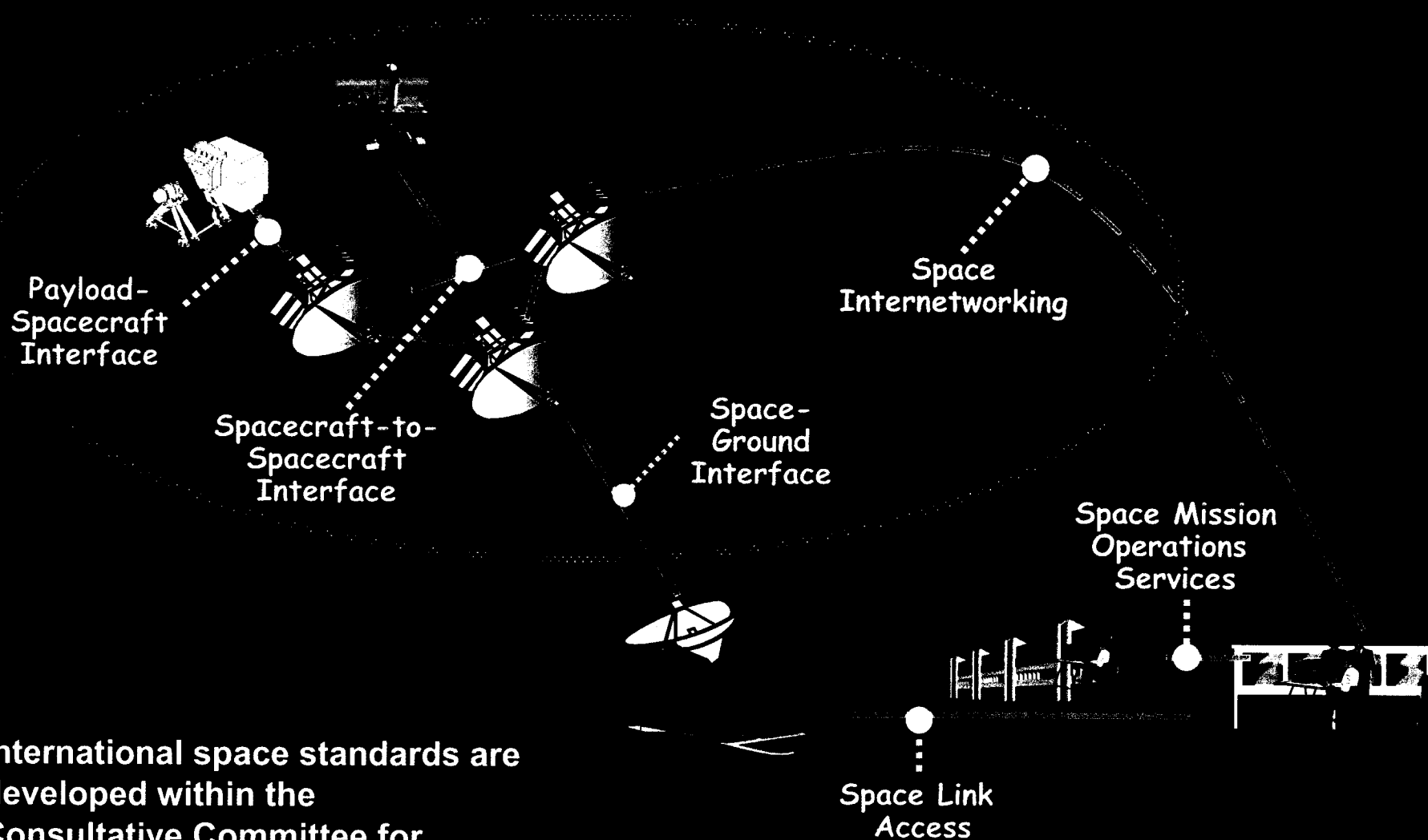
- point-to-point reliability mechanisms

*It draws upon:*

- underlying space link unit data transfer services



# Current Standardization Thrusts



International space standards are developed within the Consultative Committee for Space Data Systems (CCSDS)

# Current Space/Ground Communications Protocol Stack



Space Applications



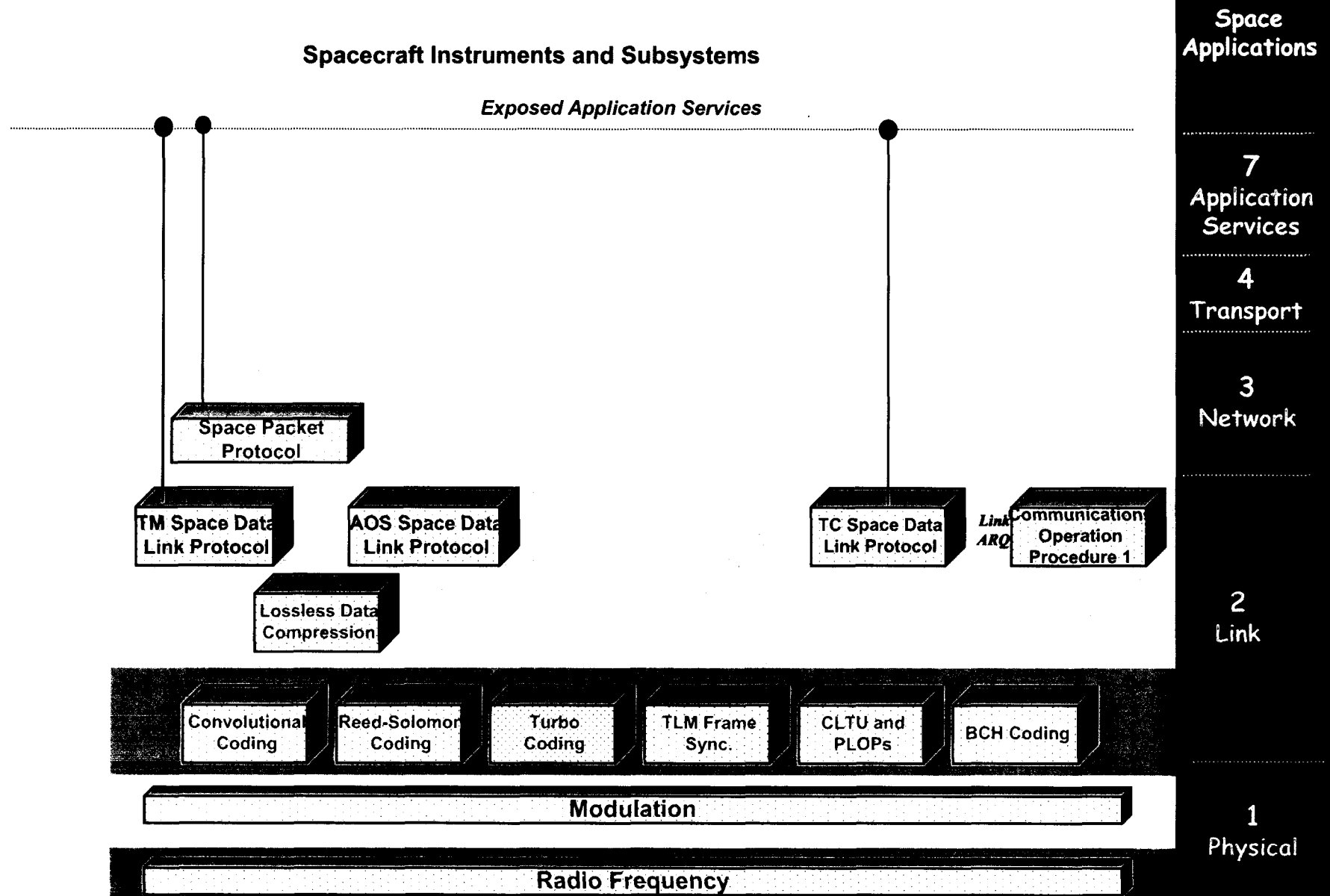
Space Networking

Space Link

Space Channel Coding

Space Wireless Frequency and Modulation

# Current Space/Ground Communications Protocol Architecture



# CCSDS: The Fleet

## Space Domain

Spacecraft Platforms

On-Board Systems

Space Qualified ASICs

~ 20 spacecraft vendors

~ 25 space component vendors

## Consultative Committee for Space Data Systems

219 Missions now using  
CCSDS Space Link Protocols  
<http://ccsds.gst.com/implementations>

## Ground Domain

Commercial Ground Networks

Command & Telemetry Data Processing

2 commercial networks

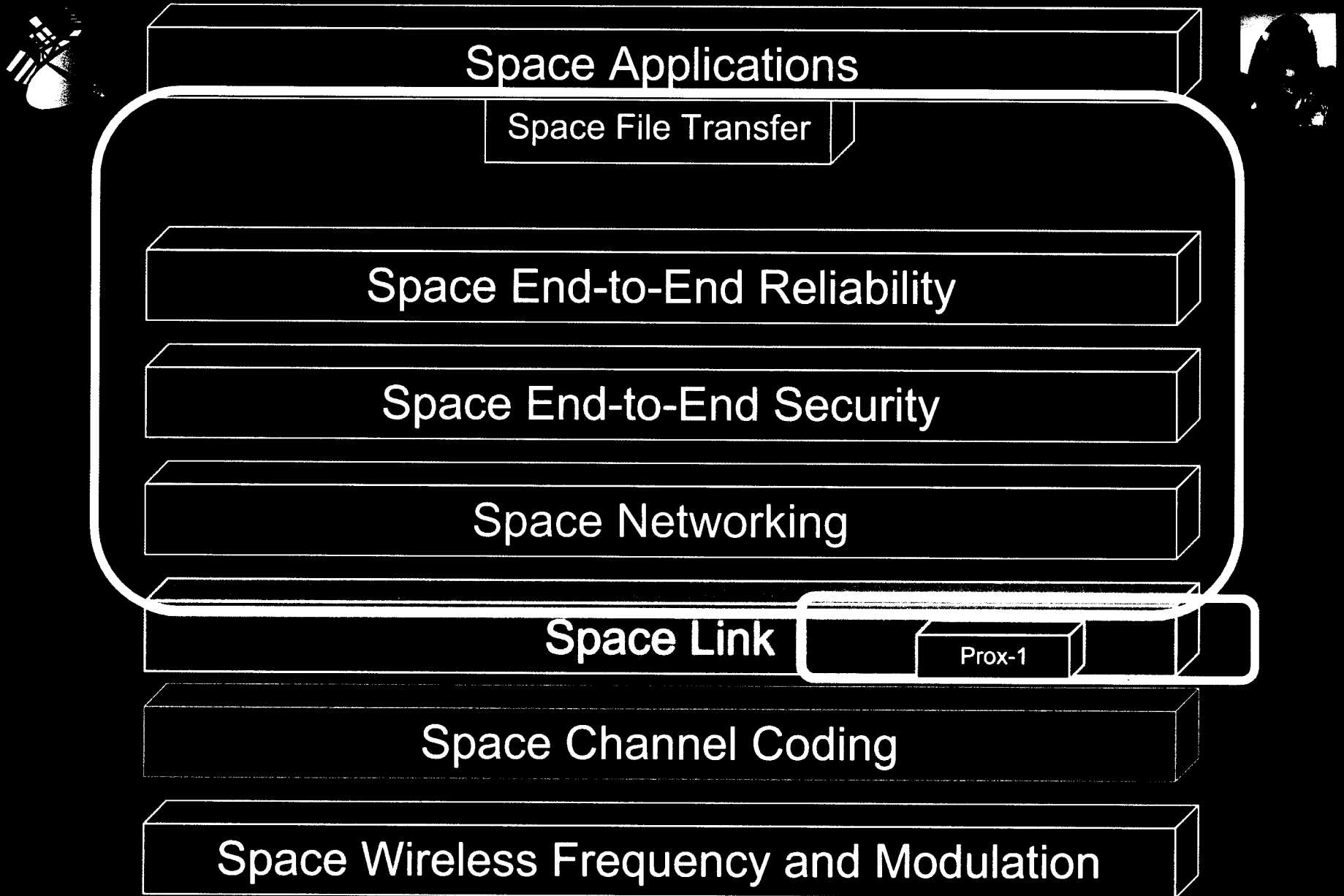
50 vendors

Extension Forward and Return Services

# The Next Few Years

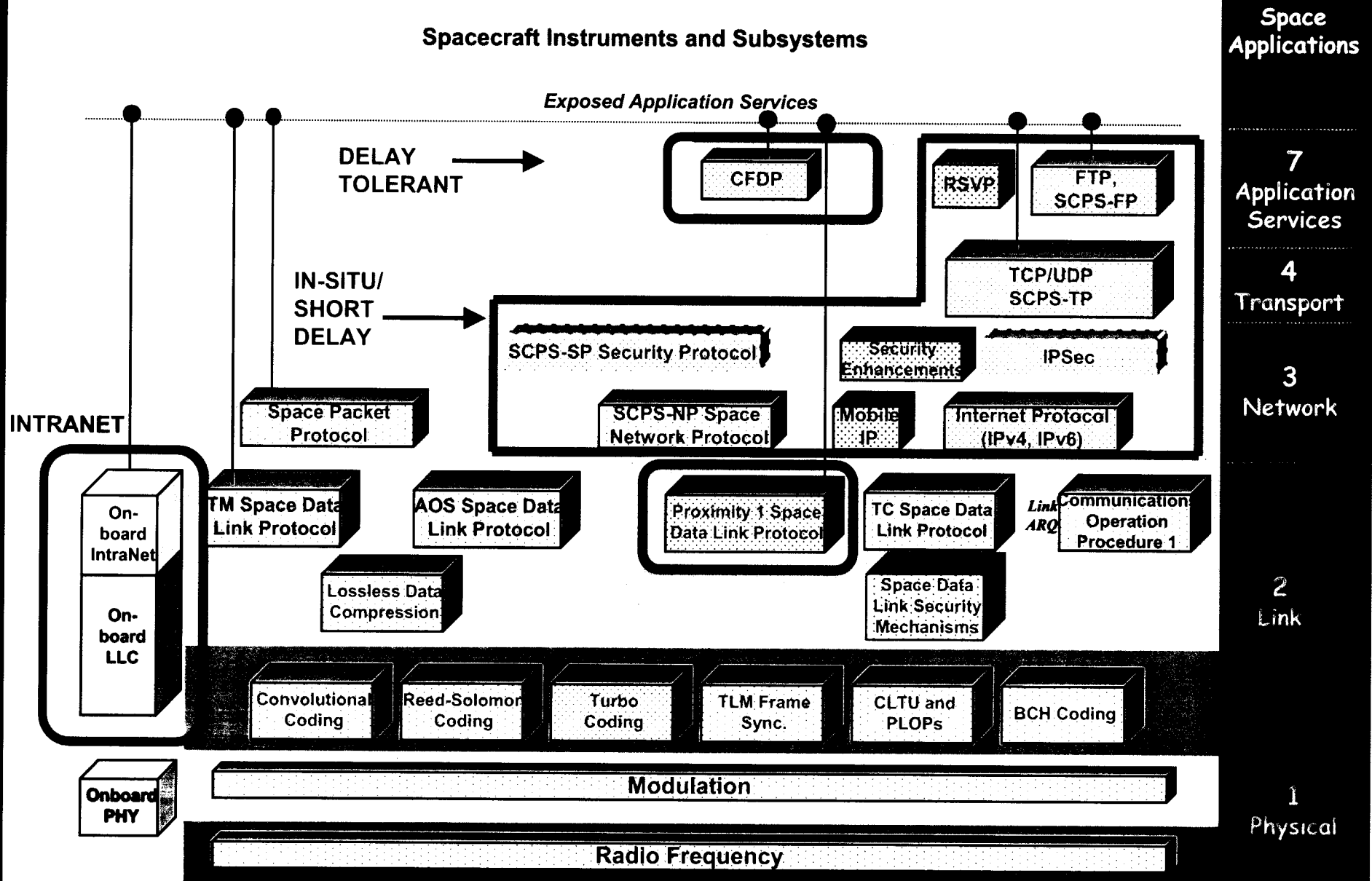
- In the next few years (2002-2005) we will evolve and migrate to add:
  1. A new flavor of CCSDS space link protocol for communicating at short range, e.g., between spacecraft in a constellation or between orbiters and surface assets
    - “Proximity 1” protocol
  2. A more networked set of upper layer standards:
    - CCSDS File Delivery Protocol (CFDP) for disconnected environments
      - Long delays, episodic connectivity
      - Custodial store-and-forward mode
      - Most missions will use this for routine space/ground data hauling
    - Internet suite for richly connected in-situ environments
      - Short delays, stable connectivity
      - Instantaneous end-end dialog
      - Onboard a spacecraft; near-Earth; on and around another planet
  3. Standardized onboard networking

# Emerging Space/Ground Communications Protocol Stack



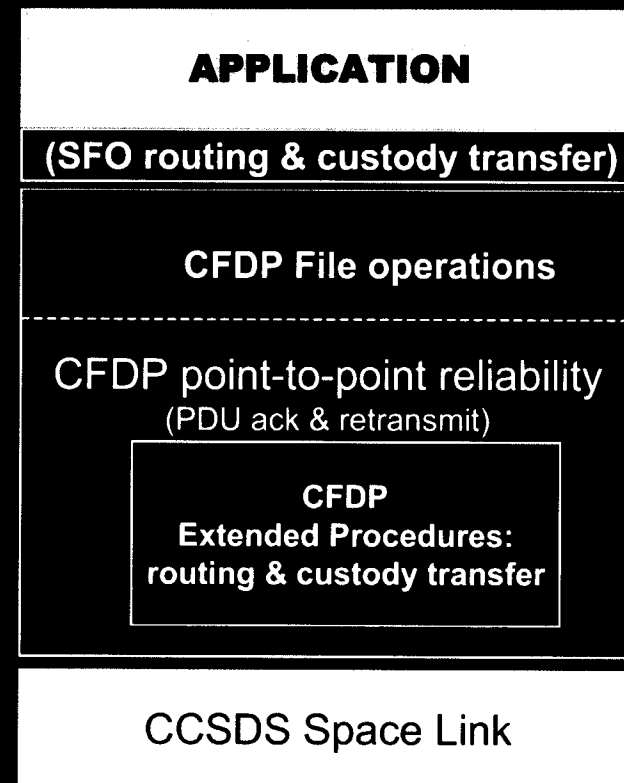
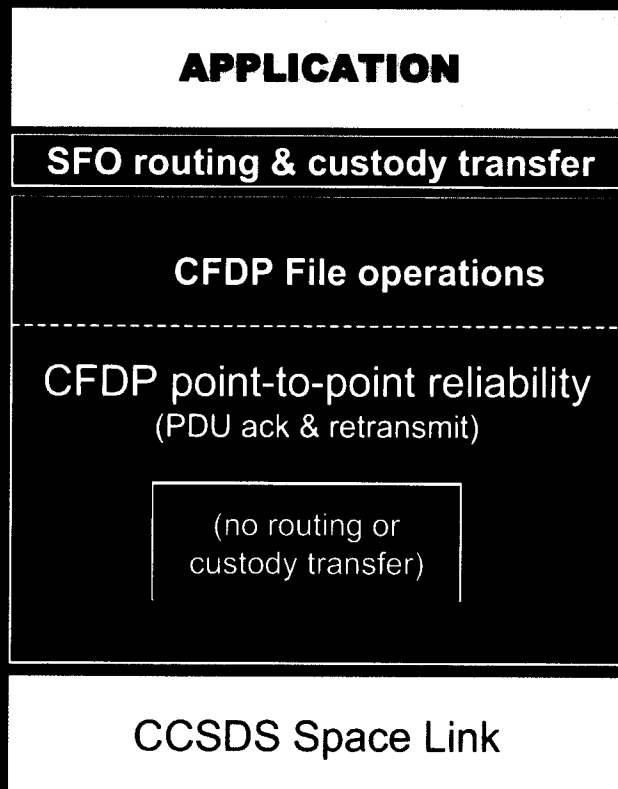


# Emerging 2002-2005 Space Communications Protocol Architecture

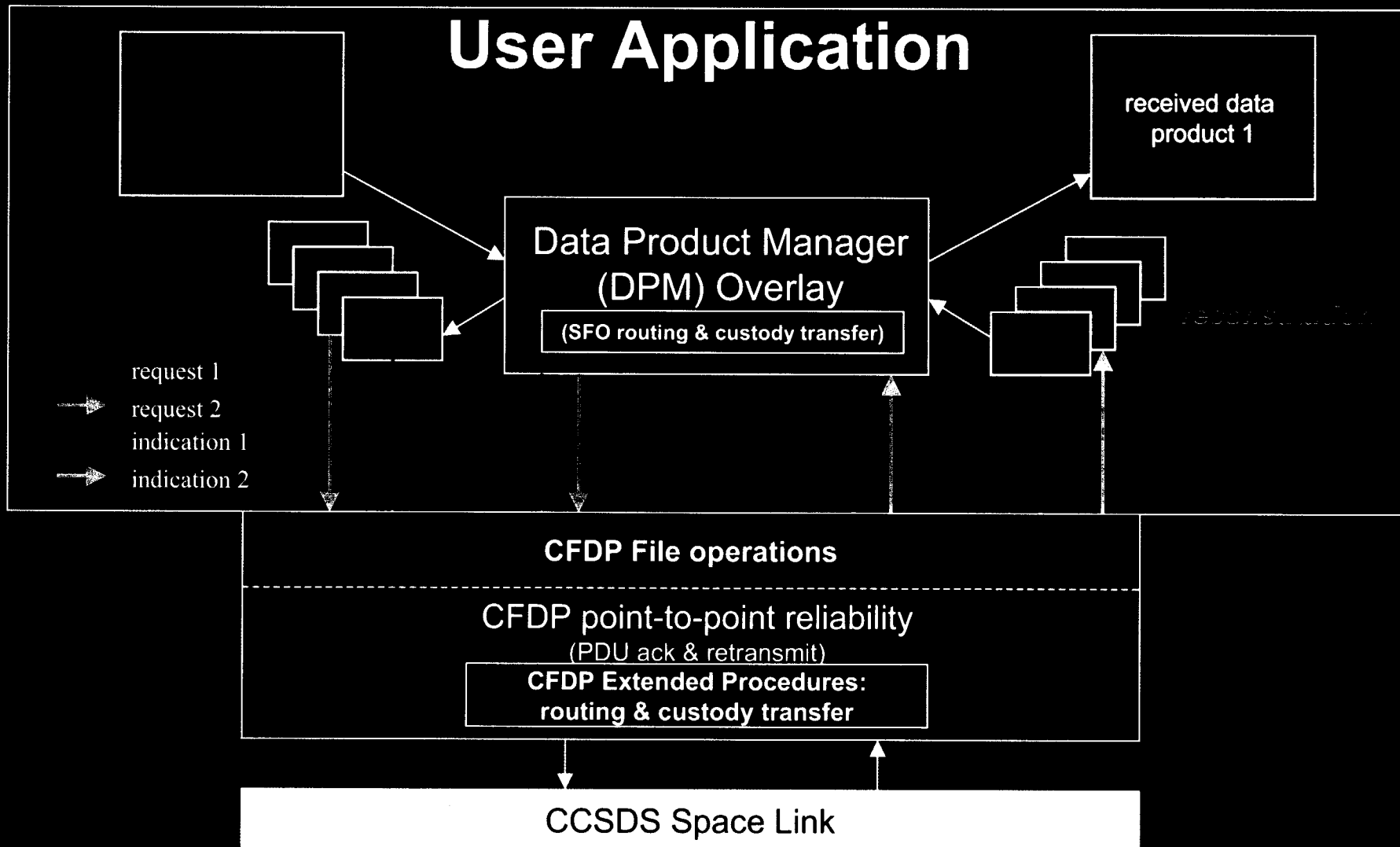


# CFDP Build 2

- Will support Scenario 3 (multi-hop, serial transfer) using either - or both - of two mechanisms:
  - A Store-and-Forward Overlay (SFO) that uses unmodified Build 1 and is not part of CFDP. This application code provides multi-hop routing and custody transfer services
  - Additional “Extended Procedures” that are part of CFDP and which provide multi-hop routing and custody transfer services. These can optionally also be augmented by the SFO for added flexibility

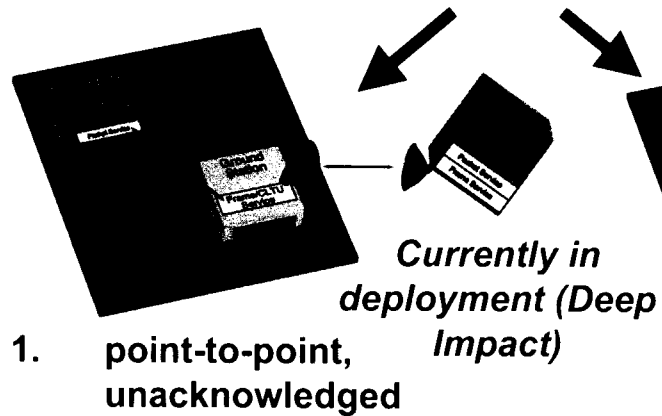


- As an interim measure to support “Mars Network” operations, Scenario 4 (multi-hop, parallel transfer) can also be supported by an *additional* “Data Product Manager” application overlay. The DPM segments user products into pieces that are small enough to transfer as independent CFDP files during a single contact, and passes state to the receiving end to enable their reconstitution.

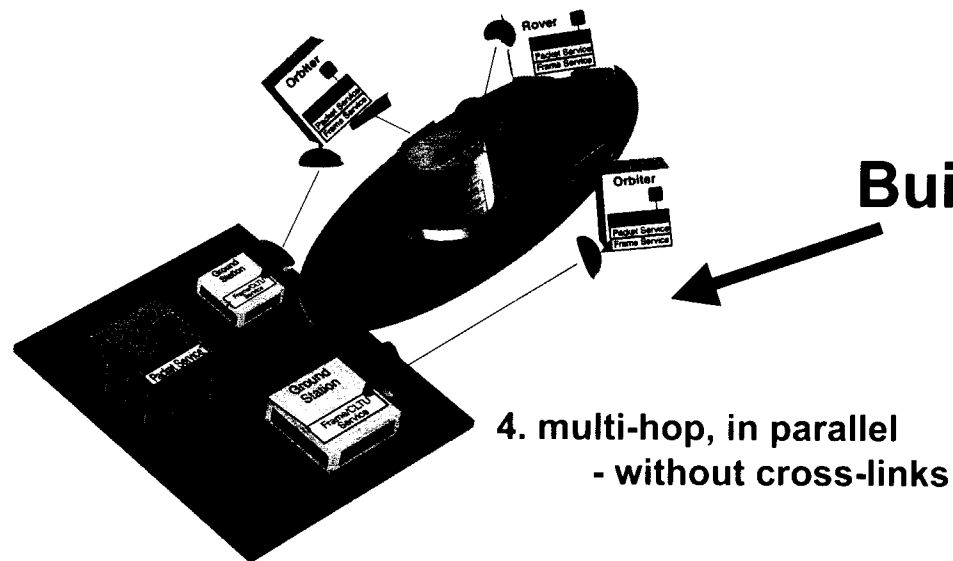
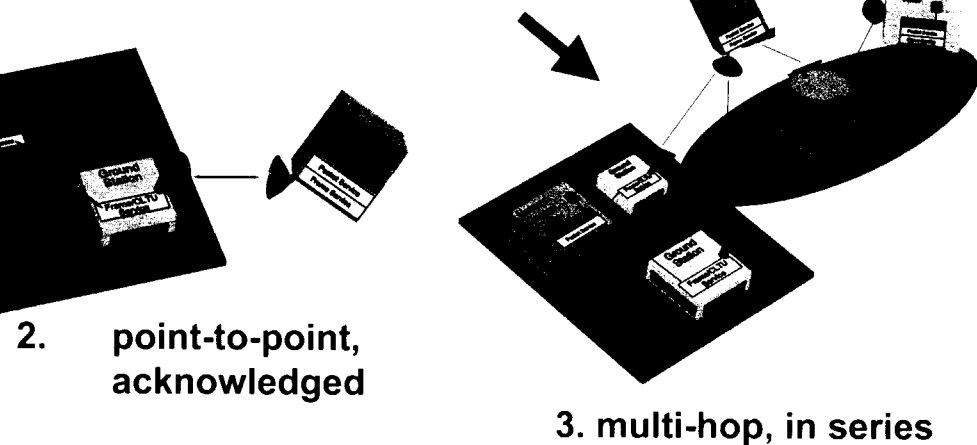


# CFDP Operations Scenarios

## Build 1 CFDP



## Build 2 CFDP

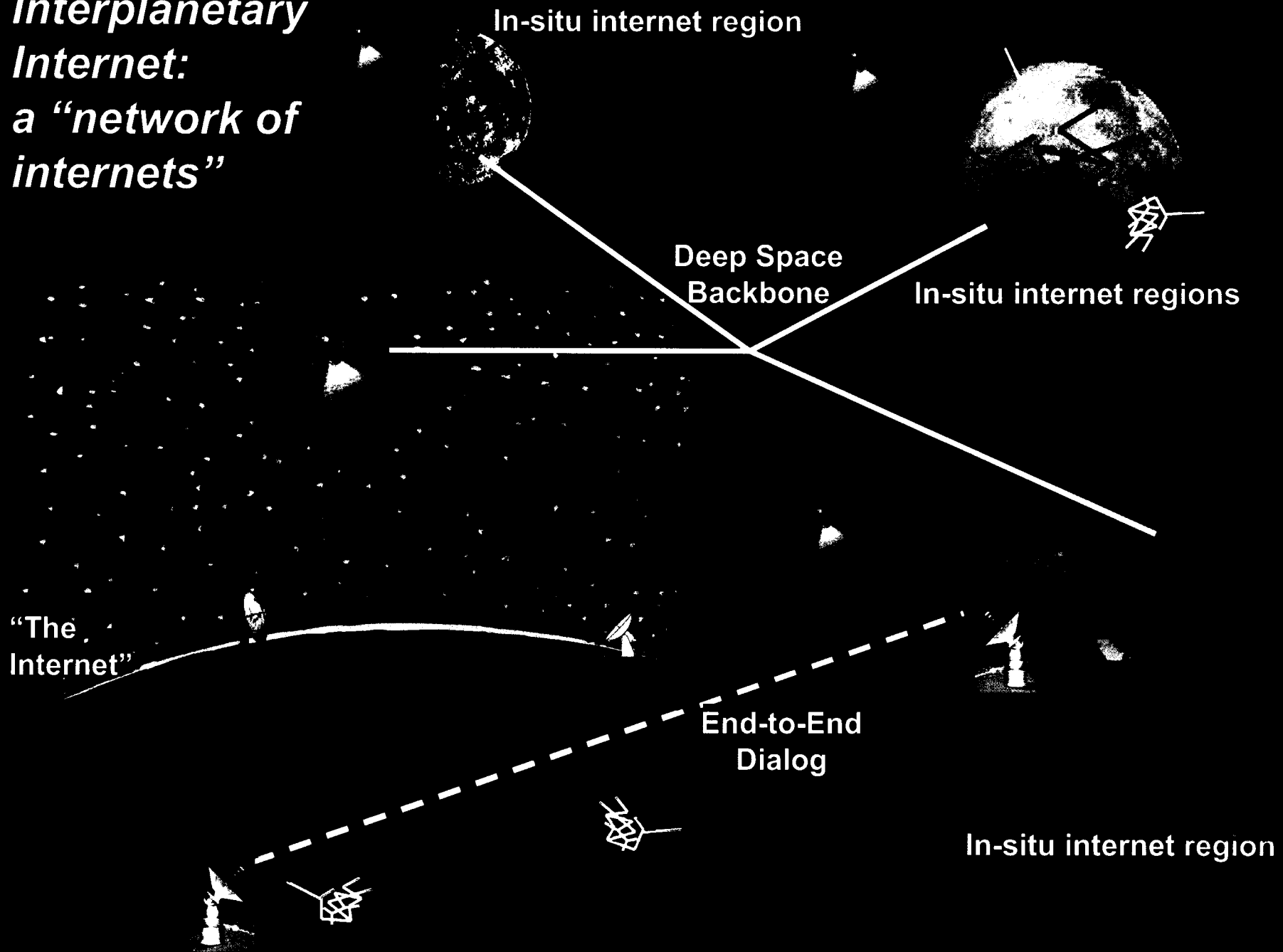


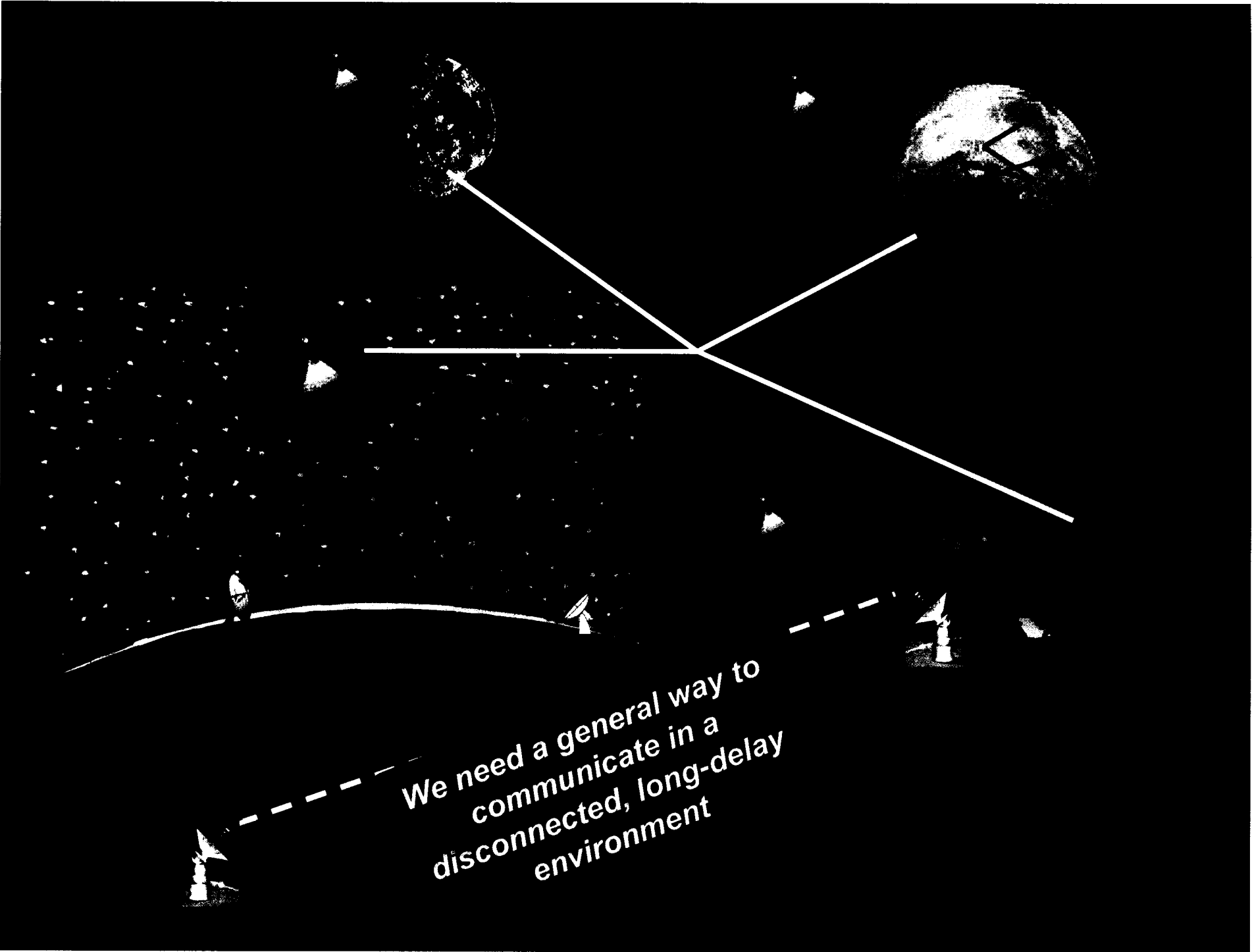


# The 5 year Scenario: fully automated end to end space mission data transfer



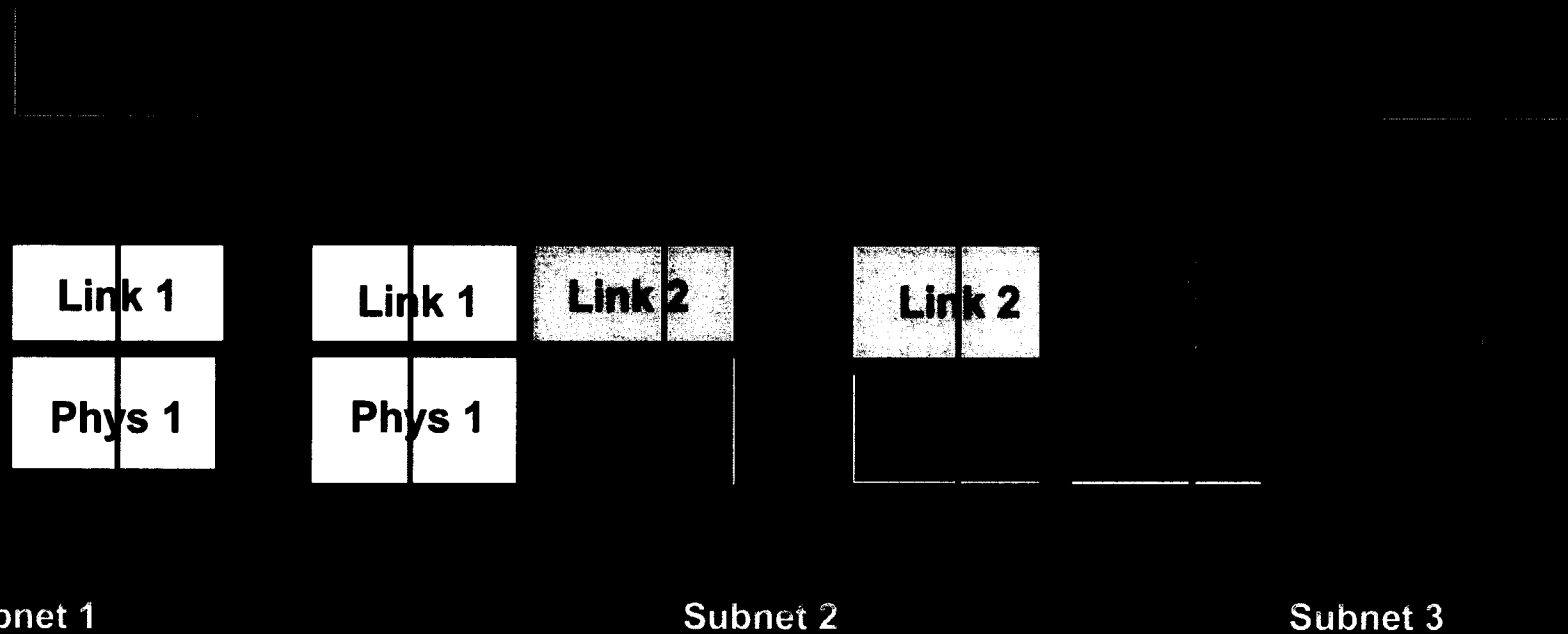
***Interplanetary  
Internet:  
a “network of  
internets”***





We need a general way to  
communicate in a  
disconnected, long-delay  
environment

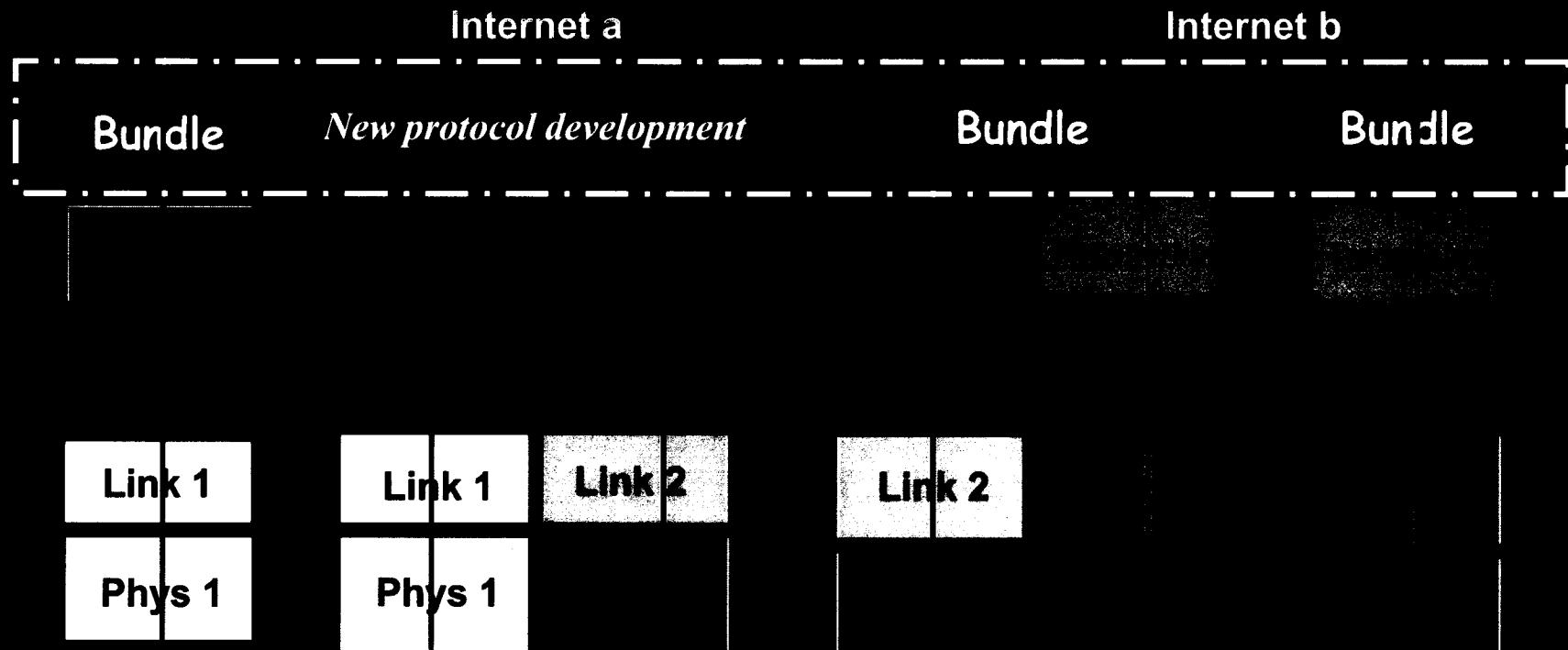
## *The Internet: a Network of Connected Sub-Networks*





# Bundles: A Store and Forward Application Overlay

The "Thin Waist" of the Interplanetary Internet



**A "network of internets" spanning dissimilar environments**

# Emerging Space/Ground Communications Protocol Stack



IPN Applications

File Transfer



**BUNDLING**

Local Space Reliability

Local Space Security

Local Space Networking

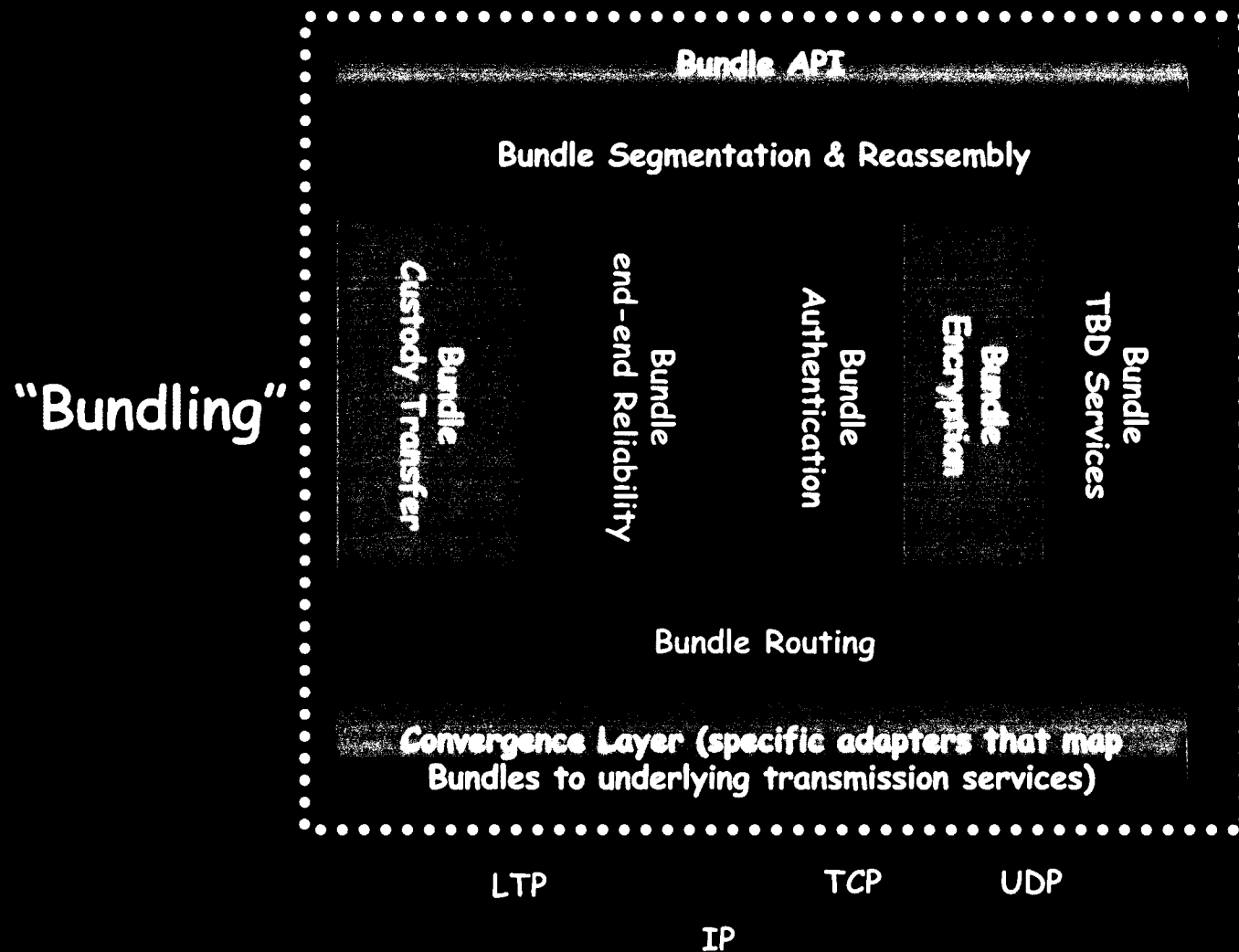
Local Space Link

Local Space Channel Coding

Local Space Wireless Frequency and Modulation

# Bundle Service Layering

e2e Applications  
(e.g., Bundle FTP, CFDP, Bundle NTP)



CCSDS  
Long-haul Link

CCSDS  
Proximity Link

SONET

Ethernet

## CFDP

- Store and forward mode
- Transfers files
- Currently point-point:
  - Static Routing
  - Implicit notion of Custody
- Monolithic
- Fairly complex; adding routing + custody transfer will make it more so
- Only of current interest to the 'space' community

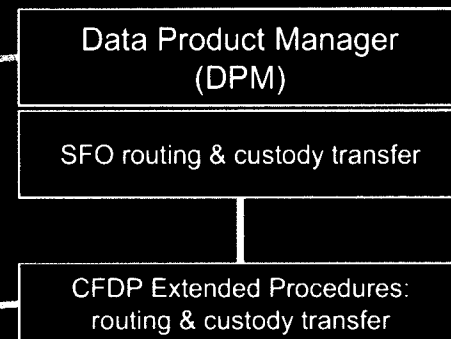
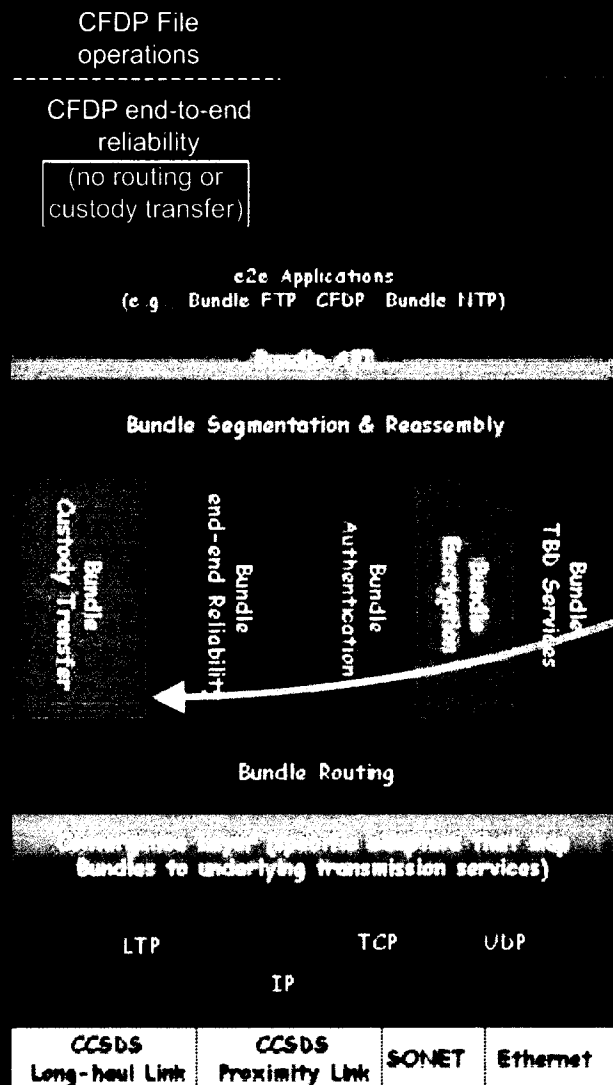
## Bundling

- Store and forward mode
- Transfers all forms of data
- Inherently networked:
  - Dynamic Routing
  - Full DTN Custody protocol
- Will be internally layered
- Quite complex, but layering will make complexity manageable
- Of wide potential interest to other communities

## Proposed Strategy

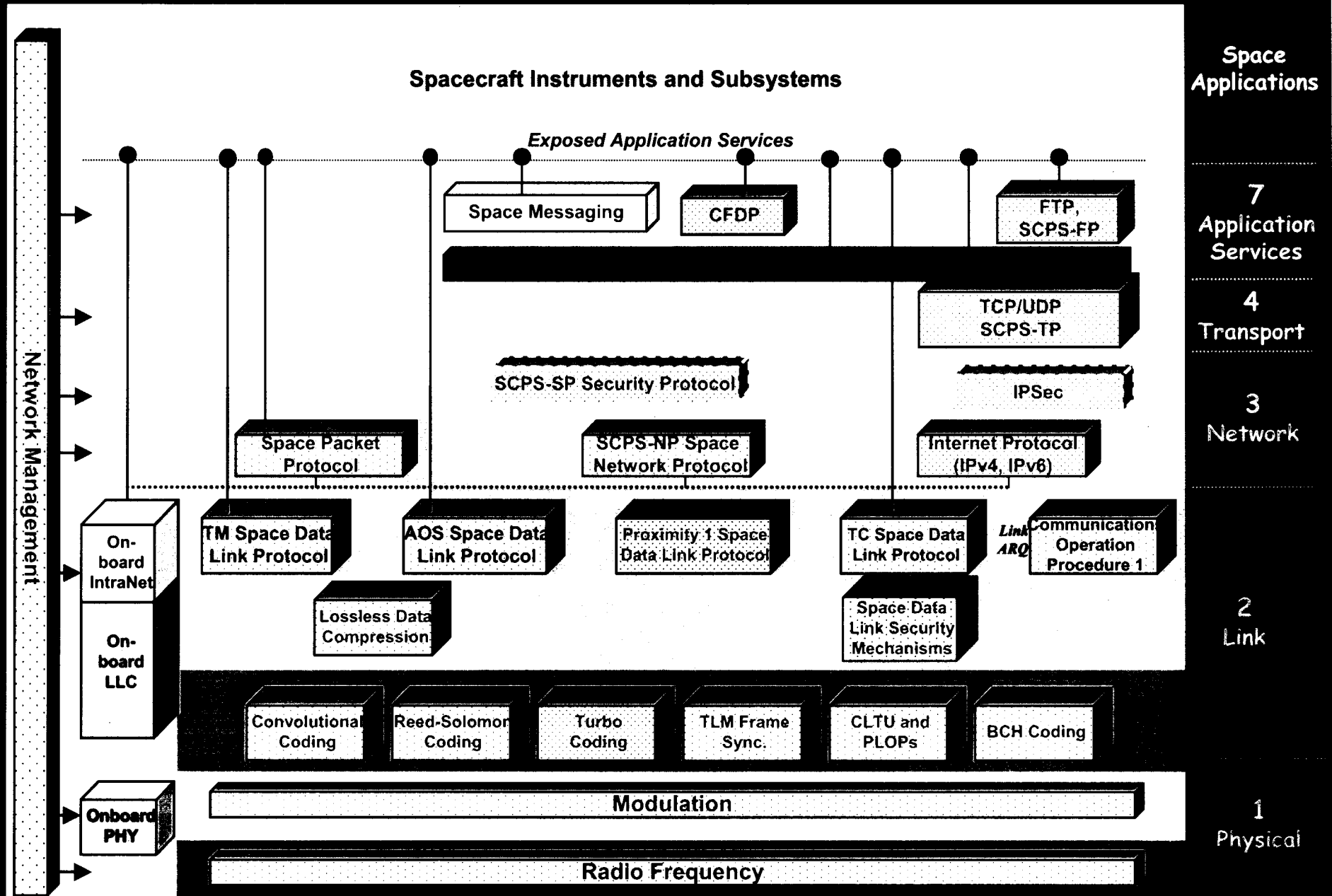
- Get CFDP into widespread use as a waypoint to Bundling
  - Avoid increasing the complexity of the core protocol
- Mobilize other DTN users to develop Bundling as a community effort
  - Broader base of users and applications = faster development and more robustness
- Infuse Bundling to handle needed complexity and simply move a stable CFDP to become an application running over Bundling

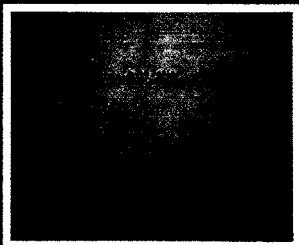
CFDP can become an  
Application running over  
Bundling: the user interface  
remains stable



Protocol Migration:  
CFDP → Bundling

# CCSDS Space Communications Protocol Architecture





IPN  
Architecture  
(Internet Draft 1)  
May 2001

DTN  
Architecture  
(Internet Draft 2)  
July 2002

First Draft  
Bundle Protocol  
Specification  
September 2002

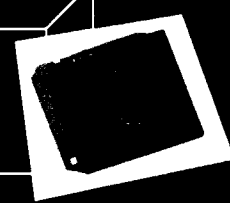
## *Bundle Specification*



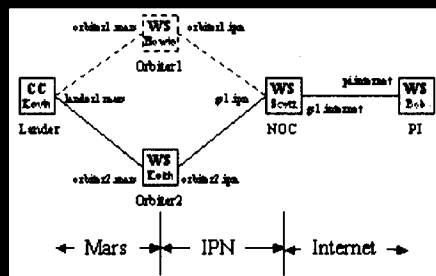
Specifications

Code base

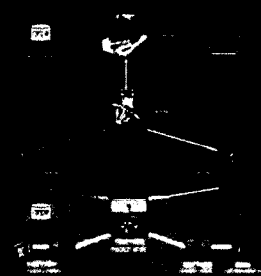
## *Bundle Prototyping*



1<sup>st</sup>  
Rough  
Code  
August  
2000

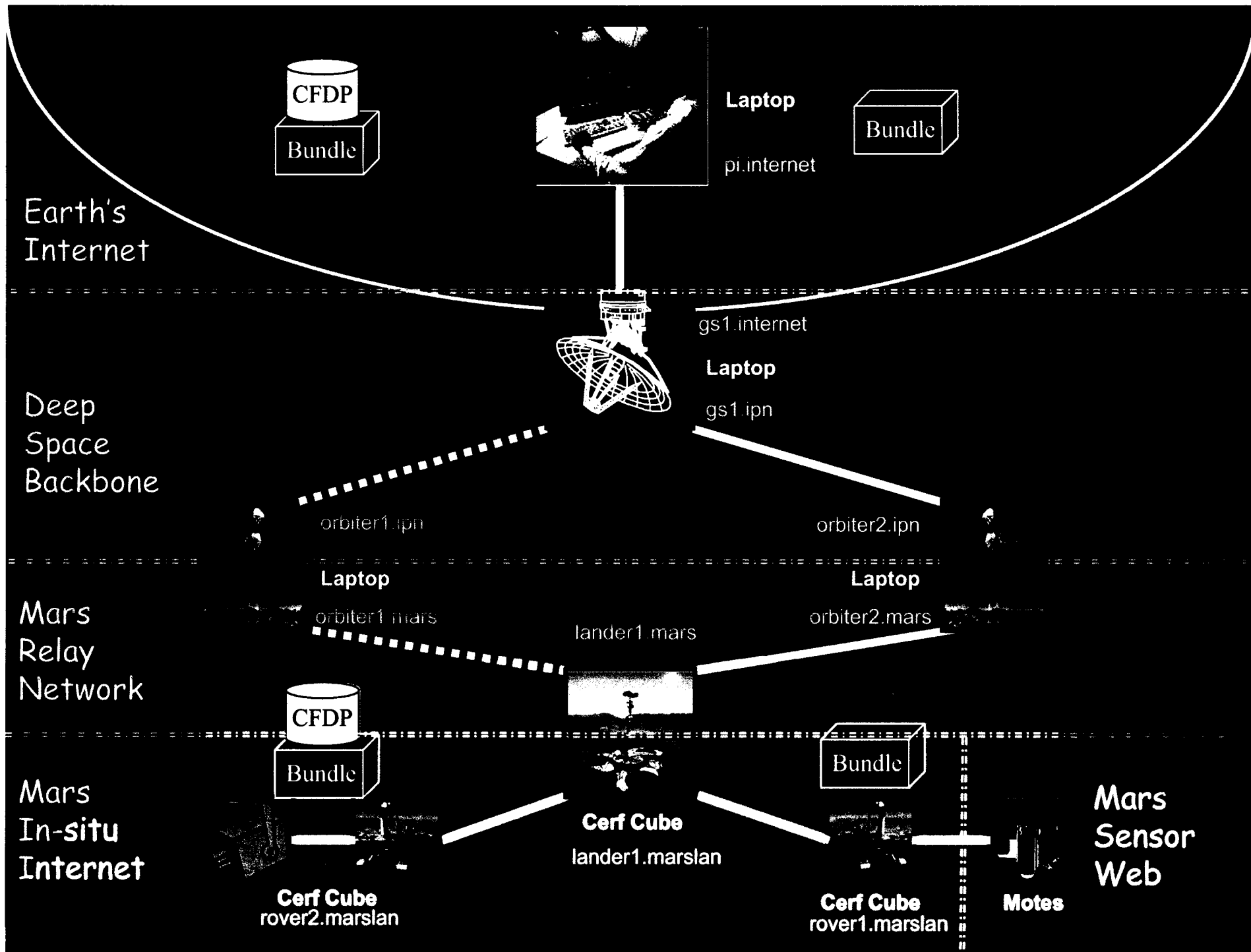


2<sup>nd</sup>  
Prototype  
Code  
May  
2002



3<sup>rd</sup>  
Prototype  
Code  
July  
2002

CFDP-over-Bundles Experiment.





Current View:

The IPN is a member of a  
family of emerging  
"Delay Tolerant Networks"

Sensor Webs

Delay can be introduced by, e.g.,  
Propagation at  $c$   
Lack of connectivity  
Lack of resources (power, buffers)  
Simplex or asymmetric channels

Interplanetary network

Stressed tactical communications

*Sensor  
Webs*

*Tactical  
Military*

...

*IPN - Public Outreach*

*IPN - Implementation*

*DTN User  
Communities*

**DTN Standardization**

- DTNRG
- CCSDS

**DTN Core Engineering**

- DTN Architecture
- DTN Design Documents

**DTN Open Source**

- Reference Implementation
- Configuration Control

*Technical Volunteers*

*DTN Technical  
Outreach*